MANUFACTURING EXTENSION PARTNERSHIPS FOR THE CONSTRUCTION INDUSTRY

by S. Shyam Sunder, David C. Cranmer, and Richard Korchak

Construction is one of the nation's largest industries and a critical asset for enhancing the international competitiveness of U.S. industry. In 1994, the combined value of new construction, renovation, maintenance and repair was about $847 billion, representing 13 percent of the gross domestic product, and the industry provided 10 million jobs.

Construction: a Fragmented Industry

The U.S. construction industry is highly fragmented, with more than a million companies participating in the market. Over 80 percent are small firms with less than 10 employees; and two-thirds have fewer than five employees. Less than 1,000 firms employ 500 or more persons. Numerous small firms compete for local construction jobs but often do not use new or improved technologies and best practices. Competition for jobs and industry fragmentation also makes it difficult for firms to support the front end costs of R&D.

Industry investment in R&D is low, only about 0.5 percent of revenue. This is almost 7 to 11 times smaller than other major sectors of the U.S. economy, and much less than other mature industries such as appliances and textiles. American construction firms also appear to do far more "environmental scanning" than actual R&D — that is, they look for new or different technologies that others are already developing or using that they might also utilize, rather than creating their own new or different methods, machinery, materials, components, or systems. As a result of this low investment in R&D, firms can fall significantly behind in adopting the best technologies and practices necessary to ensure their success in an increasingly competitive marketplace.

Contributing further to the fragmentation of the industry are the type of constructed facility, functional segmentation in the "value" chain, the large number of supplier firm groupings, and the number and mobility of specialized trades in the workforce.

New construction put-in-place in 1993 was 44 percent residential, 28 percent commercial, institutional and industrial, and 28 percent public works. The value added by each of the major functional segments in the production chain, excluding operation and use costs, is estimated by NIST economists S. Fuller and S. Weber to be: 5.6 percent for facility design; 50.9 percent for manufacture of materials and components; 30.1 percent for facility construction; 13.2 percent for maintenance, repair, and renovation; and 0.2 percent for demolition. Thus, both downstream "construction" and upstream "manufacturing" activities play important roles in what can be called Construction with a Big "C", or *the* construction industry.

Materials and equipment firms are primary suppliers to the construction industry. Among the most widely-used materials are steel, cement and concrete, masonry, asphalt, roofing and insulating materials, paints and coatings, aluminum, polymers and plastics, and geotextiles. Others, such as wood, aggregates, and gypsum, are used either directly in construction or to produce manufactured products such as concrete. For the most part, the construction materials industry is commodity-oriented; it produces few research-driven proprietary products with a significant return on investment. Typically, each material group has associated with it a large number of small to medium-sized firms that make up the supplier infrastructure. Examples include the 4,500 producers of asphalt pavement and the 4,000 ready-mixed concrete producers in the concrete construction industry. There are several opportunities where a new or improved material can perform a function better than a conventional one. Lack of knowledge, experience, or information on the part of the designer, specifier, or constructor, however, often places such materials at a disadvantage in the materials selection process.

The construction equipment manufacturing industry is another supplier group. Construction equipment selection affects project delivery time and job-site productivity. Familiarity with the major types of equipment is therefore important for construction planners and site managers. Construction has seen little automation, even though many tasks have been mechanized. The use of robots to enhance productivity and safety has begun to find application in areas such as materials handling, tunneling and excavation, and surface finishing. The construction equipment industry spends modestly on R&D (though more than other sectors of the industry) and what amount it does spend is used mainly to produce incremental improvements, e.g., in engine efficiency or equipment reliability.

Because construction is labor-intensive, human capital is a critical resource. About 73 percent of workers in construction are tradespeople, while the remaining 27 percent are managers and supervisors. Construction product quality and profitability of construction firms is largely governed by the quality, productivity, safety, and health of the labor force. Training of workers, especially for construction, maintenance, and repair of increasingly complex systems, is usually minimal.

Productivity in the U.S. construction industry has been declining since the mid-1960s, with skilled labor shortage cited as an important contributing factor. Further, no major technical support and training program in the area of occupational health and safety currently exists. With increasing demands on quality, small to medium-sized construction firms are also finding that they must adopt the best design, fabrication, and construction practices and technologies to remain competitive. This requires highly trained engineers and technicians, and a knowledgeable and skilled workforce. Trade unions have traditionally emphasized training and apprenticeship programs, but significant opportunities exist for additional programs to satisfy industry's growing demands. Such programs would have a positive effect on productivity, workers compensation, health care costs, and the ability to complete work within budget and on schedule.

The movement of best practices and technologies from the R&D phase into construction can be achieved only if the barriers that prevent them from reaching the marketplace are eliminated or reduced. Specifically, this movement of technologies requires technology transfer — the movement of new or improved technologies and practices from laboratories to innovative firms that can utilize them, and innovation diffusion — the creation of widespread uses of new or improved technologies and practices.

Important market failures result from the fragmented nature of the construction industry. There is little feedback from downstream construction activities to the upstream supplier structure and manufacturing activities. Further, the supplier structure itself is fragmented. Access to information and knowledge about new and improved technologies and practices is poor. Trade, technical, and professional associations, journals, and conferences provide forums for the presentation of R&D results, but more can be done to improve information dissemination. There is also significant potential for upgrading construction work force skill levels. That, in itself, would help create the demand pull for the adoption of new technologies and best practices.

Policies to foster innovation or entrepreneurship, or to promote an economic activity shift to high tech, are not enough. According to Sabel et al. (*Technology Review*, April 1987) modern management practices, including organizational design issues, are necessary to encourage innovative specialization in mature industries like construction. The notion that the only way to encourage innovation is to remove obstacles to competition must be reconsidered in light of evidence suggesting that cooperation in the form of joint ventures and participation in pre-competitive collective R&D efforts can be crucial in developing profitable new ideas and, possibly, help overcome many of the barriers associated with industry fragmentation.

The construction industry needs and is poised to benefit from a coordinated technology deployment program that supports the adoption of improved technologies and practices through technology transfer, barrier reduction, information dissemination, referral services, education and training, and technology diffusion. In fact, the industry's expressed need and support for technology deployment is strong and broad-based.

A full-service technology extension program could provide the almost one million small and medium-sized construction industry firms with the support necessary to improve their state-of-the-practice and to adopt new technologies. This will improve the life-cycle quality of constructed facilities and the competitiveness of U.S. industry.

A Technology Extension Program for Construction

The vision for construction is contained in the National Construction Goals, developed by the President's National Science and Technology Council, with strong endorsement by the industries of construction (R.N. Wright, *CBR*, Jan/Feb 1995). These goals focus on two priorities: better constructed facilities, and health and safety of the construction workforce. They include a call for:

- 50 percent reduction in delivery time;

- 50 percent reduction in operation, maintenance and energy costs;
- 30 percent increase in productivity and comfort;
- 50 percent fewer occupant-related illnesses and injuries;
- 50 percent less waste and pollution;
- 50 percent more durability and flexibility; and
- 50 percent reduction in construction work illnesses and injuries.

The challenges facing construction are similar to those for manufacturing. The vision for manufacturing is one based on low volume, mass-customized products and systems with large volume, mass produced and interchangeable components. Shorter product life cycles, diverse market demands, and intense global competition are driving this change towards increased agility. Thus, although construction is traditionally characterized as a service industry, it is also one of the nation's largest manufacturing activities, an activity with a pervasive impact on the U.S. economy.

The Manufacturing Extension Partnership (MEP) of the National Institute of Standards and Technology (NIST) provides a model for technology deployment in the construction industry. The MEP is a nationwide network of organizations, linked by regionally-based extension centers, to support U.S.-based manufacturers in increasing their competitiveness nationally and internationally through ongoing technical advancement. The MEP client base — 373,000 U.S. manufacturing establishments with less than 500 employees — represents an important segment of the U.S. economy. These small firms contribute more than half of the total U.S. value added in manufacturing or about 12 percent of GDP, and employ almost two-thirds of all manufacturing employees — approximately 12 million Americans. Smaller shops and factories supply many of the inputs needed by larger firms, and are an integral part of the supply chain for both commercial and defense products.

In terms of the size of the intended customer-base, i.e. small and medium-sized firms, construction is comparable to manufacturing. There are almost a million construction firms with less than 500 employees. Thus, most of the 10 million employees in construction work for small and medium-sized firms. Such firms, often subcontractors to large firms, are an integral part of the production chain for both civilian and military construction, including residential, commercial, industrial, institutional, and infrastructure construction. The impact of these firms on the health of local, state, regional, and national economies is well-established.

The need for technology deployment could be met with a coordinated program that provides full-service technology extension services, including information, knowledge, and insight into the adoption and use of modern technologies and standards and best practices that will improve the life-cycle quality of constructed facilities and the competitiveness of U.S. industry. Technologies, standards, and practices would focus on the major functional segments — namely, materials, design, construction, operation, maintenance, repair, renovation, and demolition. The types of services would encompass technology transfer and innovation diffusion, assistance in barrier reduction (e.g. codes, regulations, testing/design standards, conformance assessment, new product evaluations, model partnering agreements for alternative project delivery methods, and financing methods), information dissemination, referral services, and education and training.

Although the primary client-base would be the small to medium-sized firms in construction, the program would also serve owners, designers, specifiers, facilities managers, regulators, inspectors, suppliers, contractors, the labor force, and technical and professional organizations; all these are influential decision-making groups in the technology transfer and innovation diffusion process.

The industry's expressed need and support for technology deployment is strong and broad-based.

Expanding on the current MEP model, a program for construction would support:

- grass roots technology deployment to implement National Construction Goals;
- dedicated regionally-based technology and outreach centers for construction designed to complement and link with existing public and private programs;
- widespread diffusion of construction technologies and practices through the existing MEP network;
- a national computer-integrated knowledge systems (CIKS) network for construction technologies, standards, and practices; and
- education and training programs, including clearinghouse functions.

To help achieve the National Construction Goals by 2003, the

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President's National Science and Technology Council, with industry input, is working to develop a coordinated strategy with the following key elements: showcase demonstrations via federal construction projects; development of performance standards and conformance assessment procedures, especially in the context of emerging international quality standards; education and training programs for implementers of new technologies; a testing, evaluation and approval system for innovative construction products, processes, and services; quality systems management and partnership programs; and model agreements and legislation that support consortium formation.

The national computer-integrated knowledge systems network to be designed with, for, and by users, would provide: (1) universal electronic access through a single-point to distributed data, information, and knowledge; (2) an authoritative system to design, monitor, and manage the life-cycle performance of constructed facilities; and (3) an open testbed at NIST to build and evaluate system architectures, data representation and exchange standards, enabling information technologies, and prototype applications.

The proposed electronic network is intended to complement and link with existing and future on-line systems of participating federal, state, local,university, and industry organizations.This includes access to and use of databases, models, design-aids, best construction practices, standards and codes, regulations, and new product evaluation reports. The system is also expected to provide on-line cataloging, indexing, searching, routing, browsing, simulation, electronic commerce, collaborative authoring, help/training, referral, and distance learning capabilities. Efforts are currently underway at NIST to

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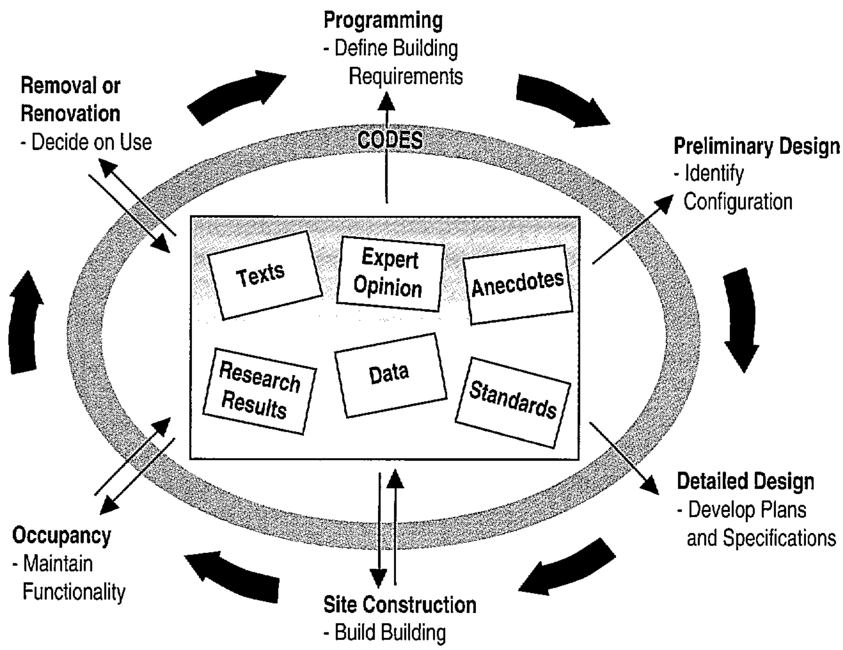
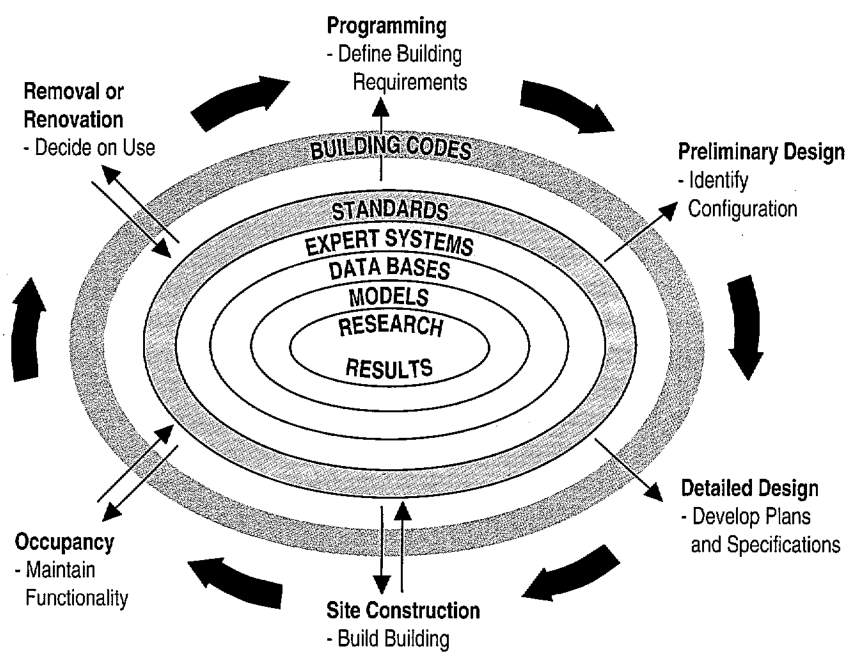
Late 20th century — forms of knowledge not integrated.



NIST is developing an open testbed for industry partners to build and evaluate a national computer-integrated knowledge systems (CIKS) network for electronic access to construction technologies, standards, and best practices via the national information infrastructure (depiction developed by G.J. Frohnsdorff).



Early 21st century — knowledge is computer-integrated.

Technologies, Standards, and Practices

- *Materials and Components:* Materials test methods and standards; quality systems; laboratory inspection and proficiency test methods; database and knowledge systems for materials design, selection, and diagnostics; non-destructive testing and condition assessment technologies; fire performance of materials and systems; economics of new materials; catalog of materials innovations.

- *Design:* Design standards and codes; design procedures and analysis methods; database and knowledge systems for systems and component design; performance prediction technologies; technologies, standards and best practices for natural hazards mitigation; fire safety assessment and suppression technologies; methods for predicting life-cycle performance and economics of constructed facilities; catalog of design innovations.

- *Construction:* Construction systems and methods; constructability and high-volume materials processing; construction equipment; automation and robotics; standards for electronic representation of project data; project control methodologies; cost indices and estimation methods; construction contracting and financing methods; quality in construction; catalog of construction innovations.

- *Energy and Environment:* Regulations and standards for construction and operation of constructed facilities; analysis of energy efficiency, including demand modeling; energy efficient and environmentally sustainable technologies for materials manufacturing, construction, lighting, HVAC, mechanical systems, water use, and waste disposal; alternative and renewable energy sources; advanced technologies such as cool materials and intelligent building systems; catalog of innovations.

- *Inspection and Maintenance:* Regulations and standards; inspection and maintenance methods and procedures for constructed facilities under normal conditions (routine operation and use) and unusual conditions (accidents, natural hazards); knowledge and automated systems; catalog of innovative inspection and maintenance methods.

- *Repair, Renovation and Rehabilitation:* Regulations and standards; repair, renovation and rehabilitation methods and procedures for constructed facilities due to normal deterioration (e.g. fatigue, environmental) and unusual damage (accidental, natural hazards); catalog of innovative repair, renovation and rehabilitation technologies.

address issues such as intellectual property rights, payment for documents, and exchange of draft documents arising from such electronic commerce activities. Most services would thus be accessible at any point on the network or electronically from a remote site via the national information infrastructure.

Curricula and complementary teaching aids are needed for use in academic and vocational programs, including general workforce training courses in new technology, teamwork, quality improvement, and new market strategies. These educational and training programs will provide the workforce, including designers, specifiers, constructors, and regulators wider access to relevant knowledge, information and industry experience.

To make this happen, imaginative new delivery mechanisms are needed, including networked distance learning systems. These programs could also provide electronic access to occupational injury data for the workforce as well as short courses and materials for understanding and implementing health and safety objectives in construction. High-risk manual work could be reduced by educational and training programs that enable firms to integrate automation technologies and manufacturing processes.

How Can You Help Create This Program?

Ideally, work towards full-scale implementation of a technology extension program for construction would commence immediately. But recognizing that an approved program could take two or three years to develop, MEP has started exploratory efforts with the construction industry.

With the MEP focus on construction in its formative stages, NIST's Building and Fire Research Laboratory (BFRL) has initiated a detailed, year-long planning study in collaboration with the MEP to create a Construction Technology Extension

MEP – A MODEL FOR CONSTRUCTION

NIST, an agency of the U.S. Department of Commerce, began the Manufacturing Extension Partnership (MEP) program in 1988 after passage of the Omnibus Trade and Competitiveness Act (PL 100-418, 15 U.S.C. 278n). The first three extension centers were established in 1989. The system now has 60 centers in 42 states and Puerto Rico, comprising both regional technology centers and smaller outreach centers, and 40 projects which support them via pilot demonstrations for new services, or provide environmental assistance to smaller manufacturers.

An industry-driven program, MEP builds upon the foundation of existing state and local industrial extension services and derives its strength, service structure, and strategic direction from the experience-base and diversity of its state and local service delivery partners. MEP's federal resources and programs are intended to complement, not compete with those of the state and local regions and the private sector. This is achieved through value-added partnerships with national, state and local organizations, both public and private.

The MEP also provides matching grants and technical assistance to states which are building or strengthening their industrial extension infrastructure. Support is provided for planning, regional linkages, and follow-up support for implementation. Industry associations play an important role both in defining technology needs and in providing strong links to significant industry sectors.

The manufacturing extension centers themselves are regionally-based, technically proficient organizations with a range of technology transfer and management assistance resources. They are operated by non-profit organizations with strong local ties. Specifically, the centers help manufacturers become aware of the benefits of applying advanced technology to their own businesses, and learn how to choose and apply technologies and "best practices" on the factory floor. Services delivered respond to the individual needs of a small firm or the collective needs of many firms in a region.

Each center provides technology analysis, information and assistance, and linkages to essential related services such as workforce training, business systems, financial planning, marketing, and other services that impact a company's competitiveness. In addition, the MEP provides support and enhancing services such as standardized evaluation systems, field agent training, tool development, workshops, and other services designed to improve the overall competitiveness of the manufacturing industry.

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Program (CTEP). Industry input is essential to this process as we develop the concept and strategy for the program. The focus of the planning effort is to:

- define the most important services and the mechanisms for providing them;
- identify existing public and private sector activities/services that should be linked;
- identify areas (technical and geographic) that needed new centers;
- identify alternative funding sources to support CTEP operation, including an assessment of industry's ability to finance needed services;
- determine if other industries offer a model to guide CTEP development (e.g. the medical health care industry, agriculture, automobile manufacturing and repair); and
- identify organizations willing to work with NIST to develop the program.

The Civil Engineering Research Foundation is leading an effort, in partnership with NIST, to marshal the resources needed to develop the concept and strategy plan for CTEP to enable grass roots implementation of the National Construction Goals. A steering committee of industry leaders is being formed to help guide this planning effort and to organize and conduct a workshop, tentatively set for March 7, 1996, that will provide input to the plan.

As we define and chart our course, it is important that we hear from a broad cross-section of interested individuals and organizations affiliated with the construction industry about your needs, priorities, and kinds of technologies and services that would enable your firm or industry group to better compete in the marketplace. CBR

The authors are with the U.S. Department of Commerce, National Institute of Standards and Technology, Gaithersburg, Maryland. S. Shyam Sunder is Manager of the High-Performance Construction Materials and Systems Program in the Building and Fire Research Laboratory; David C. Cranmer is Manager of Strategic Partnerships and Richard Korchak is the Southern Regional Manager for the Manufacturing Extension Partnership.

For more information, contact S. Shyam Sunder at 301-975-6713, fax 301-990-6891, or e-mail: sunder@enh.nist.gov.